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PONDEROSA PINE SAPLINGS RESPOND TO CONTROL OF SPACING AND UNDERSTORY VEGETATION

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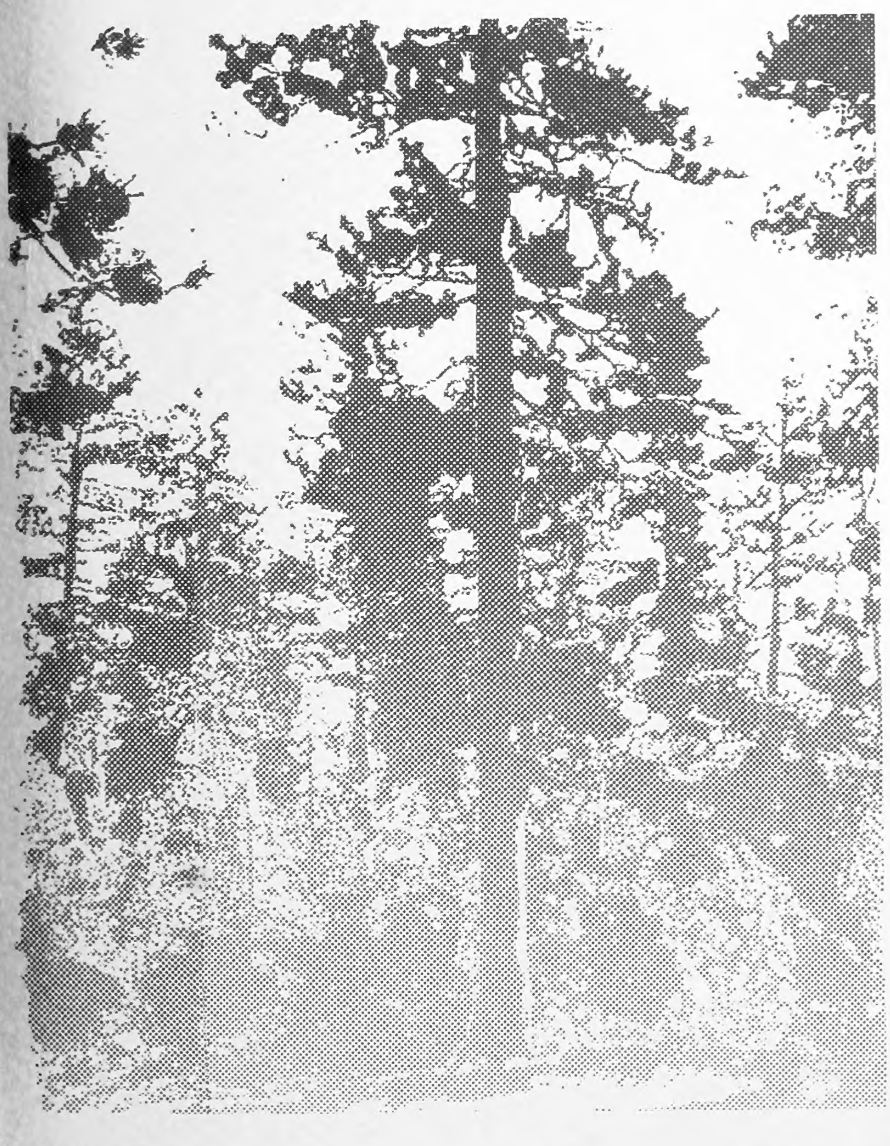

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INTRODUCTION

Recent forest inventories indicate that about 5 million acres of commercial ponderosa pine forest land east of the Cascade Range in Washington and Oregon have a dense understory of suppressed trees.[1] On many additional acres, the overstory has been removed, leaving dense thickets of 40- to 80-year-old, sapling-sized trees. Some managers have chosen to thin these residual stands while others, still hesitant about the investment in thinning, have elected to let the understory develop naturally. Most agree, however, that if these stands are to make reasonable progress toward producing a merchantable product, they must be thinned.

The type of precommercial thinning selected for these stands may imply the product mix of a multiple use manager or the anticipated market of a private company. If a forester chooses a narrow spacing, he is forecasting a market for small trees by the time the next thinning is needed. On the other hand, choice of a wide spacing implies that the forester is aiming toward larger trees suitable for sawing or peeling or that he is interested in increasing forage and/or water yields. Both routes may be equally productive.

Since optimum tree spacing depends on product objective, the forester must know the growth possibilities at a number of spacings to satisfy varied management objectives. In addition, he needs to know the competitive effects of understory vegetation, soil moisture availability, and limb development, all of which can affect the production of useful wood.

[1] Personal communication with Donald R. Gedney, Forest Survey, Pacific Northwest Forest and Range Experiment Station, Portland, Oreg.

This paper presents 8-year-growth results from a spacing study designed to give the manager a wide range of alternatives from which to choose an initial spacing.

The first 4-year results from this experiment were presented in 1965 (*1*).

STUDY AREA

The study is located on the Pringle Falls Experimental Forest, 35 miles southwest of Bend, Oreg. Study plots are on an east-facing slope at about 4,400 feet elevation. Annual precipitation averages 24 inches, approximately 85 percent of which falls between October 1 and April 30. A snowpack of 24 inches is common from January to March. Daytime temperatures during the growing season range between 70° and 90°F. Nights are cool with occasional frosts. Site index of old-growth ponderosa pine in the area indicates a height of 78 feet at age 100, average site quality IV (*10*).

Soil is a regosol developed in dacite pumice originating from the eruption of Mount Mazama (Crater Lake) 7,300 years ago. The pumice averages 33 inches deep and is underlain by sandy loam paleosol developed in older volcanic ash containing cinders and basalt fragments. The Lapine soil series is the most common although a few areas of Longbell[2] soil occur in the study area.

Before study installation, the timber stand consisted of old-growth ponderosa pine averaging 17,000 board feet per acre with a 40- to 70-year-old understory of 1- to 5-inch saplings as dense as 20,000 stems per acre on

[2] Tentative series not yet correlated.

remaining trees after this competing vegetation was removed. Thinning to a wide spacing stimulated the growth of understory vegetation such as manzanita, snowbrush, bitterbrush, and sedge. In some instances, these understory plants seemed to offer as much competition to released trees as if four times as many trees were left. Removal of understory vegetation allowed additional amounts of soil moisture to be available for tree growth.

Diameter Growth

Tree spacing significantly affected diameter growth, during both the first and second 4-year growth period (fig. 3). Orthogonal comparisons showed a real trend, in both growth periods, of increasing diameter growth with increasing tree spacing. For example, during the last period and where understory vegetation was left, trees at the narrowest spacing grew at an average rate of 1.3 inches per decade compared with 3.5 inches at the widest spacing. Where vegetation was removed, trees at the widest spacing grew at a rate of 5.9 inches per decade compared with 1.7 inches at the narrowest spacing. Although diameter growth rates increased at the widest spacings in the second period, the slight falling off of growth from the first to the second period at the narrowest spacings was not statistically significant.

Ratios of wood to bark were statistically the same for all treatments. Thus, varying bark growth rates are not involved in the diameter growth shown in figure 3.

Understory vegetation has offered considerable competition to diameter growth, especially at the wider spacings. During the second period, for example, tree growth at the widest spacing was reduced about 40 percent by understory vegetation. As numbers of trees increased, the effect of understory vegetation on growth diminished. The highly significant spacing times understory vegetation treatment interaction indicates this effect is probably real rather than the product of chance variation.

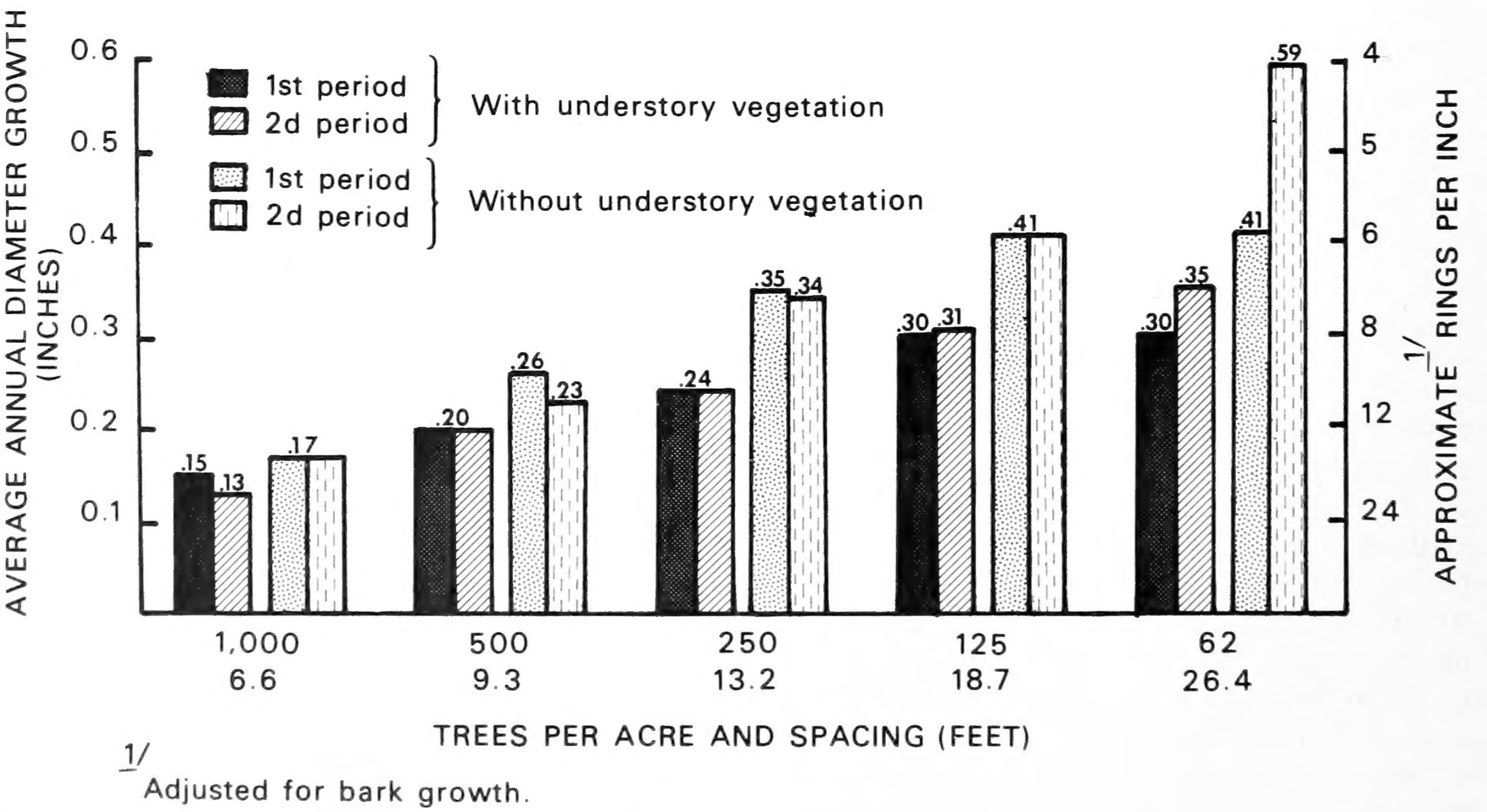


Figure 3.–Average annual diameter increment of ponderosa pine saplings during the first and second 4-year growth periods.

Orthogonal comparisons between treatments indicate that trees spaced 18.7 feet are competing with one another after only 8 years. Trees spaced 26.4 feet may be competing, but we can't really tell because we had no wider spacing for comparison. However, earlier growth studies[5] with free-growing ponderosa pine trees (trees growing without competition from other trees) in central Oregon indicate that trees spaced 26.4 feet in this study, and having no competing understory vegetation, are probably free growing after 8 years.

Where vegetation was removed, the largest trees of each spacing grew best. For example, in figure 4 for the 62 largest, well-distributed trees per acre selected from a stand containing 1,000 trees per acre, the average diameter growth rate (0.29 inch) is nearly twice that of the average of all trees (0.16 inch) in the stand. Even though the growth rate of larger trees was greatest in each treatment, they were held back by other trees. To illustrate, the average growth of the stand containing just 62 trees per acre was about 0.5 inch per year, but as we add two, four, eight, and 16 times as many trees, the growth of the 62 largest trees in each treatment became less and less until it finally reached 0.29 inch in the 1,000 trees per acre stand (fig. 4). Therefore, trees occupying the most favorable position in the stand were not independent of stand density.

[5] Unpublished progress report on file in the Pacific Northwest Forest and Range Experiment Station's Silviculture Laboratory, Bend, Oreg.

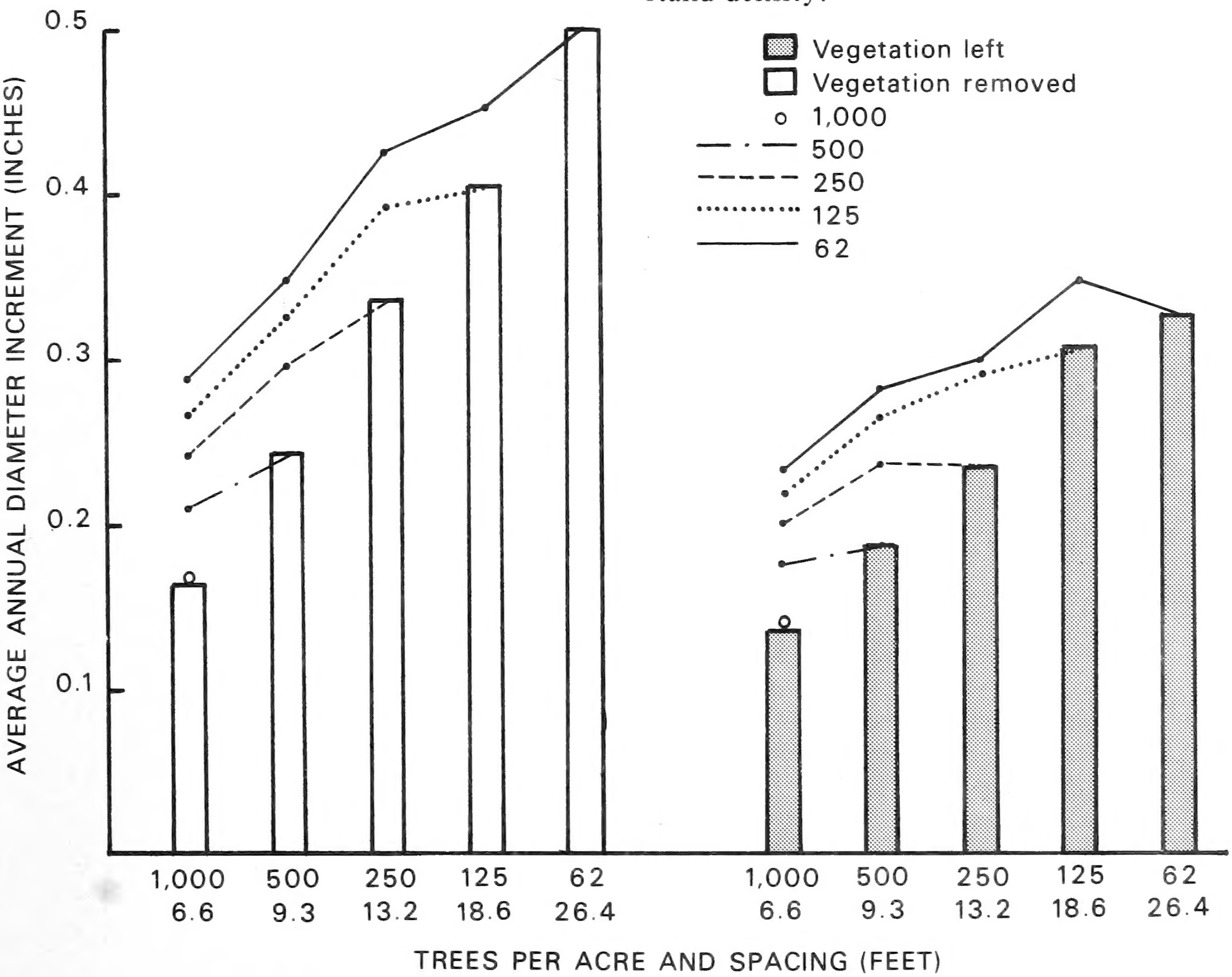


Figure 4.—Average annual diameter increment of ponderosa pine saplings thinned to various spacings (1959-67). Bars show diameter growth for total number of trees at each spacing. Points above bars show growth of the stated number of the largest well-distributed trees within the stand.

Similar trends existed where understory vegetation was left, but differences between spacings were not so pronounced, due to the competitive effect of understory vegetation. Exceptional diameter growth of individual trees in denser stands could almost always be accounted for by localized wide spacing or a lack of competing understory vegetation.

Basal Area

Basal area increased to about 56 square feet per acre at the closest spacing (table 1), or about 25 percent of that found in fully stocked normal stands past age 50 (*10*).

Basal area increment over the 8-year period was greatest at the closest spacing where the growing stock base was highest. Increment decreased progressively as spacing was increased. However, basal area was accumulating most rapidly per unit of initial basal area at the wide spacings where diameter growth was the greatest. For example, at the widest spacing (62 trees per acre) where understory vegetation was removed, basal area increased to about eight times its initial quantity directly after thinning. Where 500 trees were left, the basal area increase was only 4.7 times. Also, where understory vegetation was removed on the widest spacing (26.4 feet) basal area was almost as high as that of the closest spacing only 8 years ago. This indicates a rapidly expanding growing stock base at the wide spacings which could lead to reasonable wood production per acre on fewer trees in the near future.

Height Growth

Height growth did not respond dramatically to increased growing space until the second 4-year period, although spacing did significantly affect growth during both periods (fig. 5). Greater growth was observed

Table 1.—*Average basal area per acre of ponderosa pine saplings directly after thinning and 4 and 8 years later, and 8-year basal area increment*

Treatment	Trees per acre and spacing (feet)				
	1,000- 6.6	500- 9.3	250- 13.2	125- 18.7	62- 26.4
	Square feet				
Vegetation left:					
1959	21.8	7.9	5.4	3.3	1.5
1963	36.9	17.1	12.3	7.9	3.7
1967	55.9	31.6	21.8	14.4	7.5
8-year increment	34.1	23.7	16.4	11.1	6.0
Vegetation removed:					
1959	15.8	7.9	4.9	4.3	1.6
1963	31.4	21.4	14.8	11.5	4.9
1967	52.4	37.4	30.1	22.2	13.0
8-year increment	36.6	29.5	25.2	17.9	11.4

at progressively wider spacings. For example, during the first period, where understory vegetation was removed and 1,000 trees per acre left, trees grew an average of 0.2 foot per year compared with 0.5 foot where only 62 trees were left. In the second period, however, trees at the widest spacing averaged 1.2 feet per year.

Understory vegetation reduced height growth on all spacings during both periods except during the first period where trees were spaced 6.6 feet. Growth reductions from understory vegetation were more severe as spacing increased. A maximum reduction in height growth of 42 percent occurred in the second period at the widest spacing.

Height growth of individual trees ranged from an unmeasurable amount for some trees at the 6.6-foot spacing to almost 2.0 feet per year for one tree at the widest spacing. During the first period growth at the widest spacing was erratic, with some trees growing a foot or more in a year and others much less. During the second period, however, variation was greatly reduced at the wide spacings because all trees tended to grow uniformly well. Evidently there is a time lag, closely related to tree density, before trees are able to respond fully to their new spacing environment.

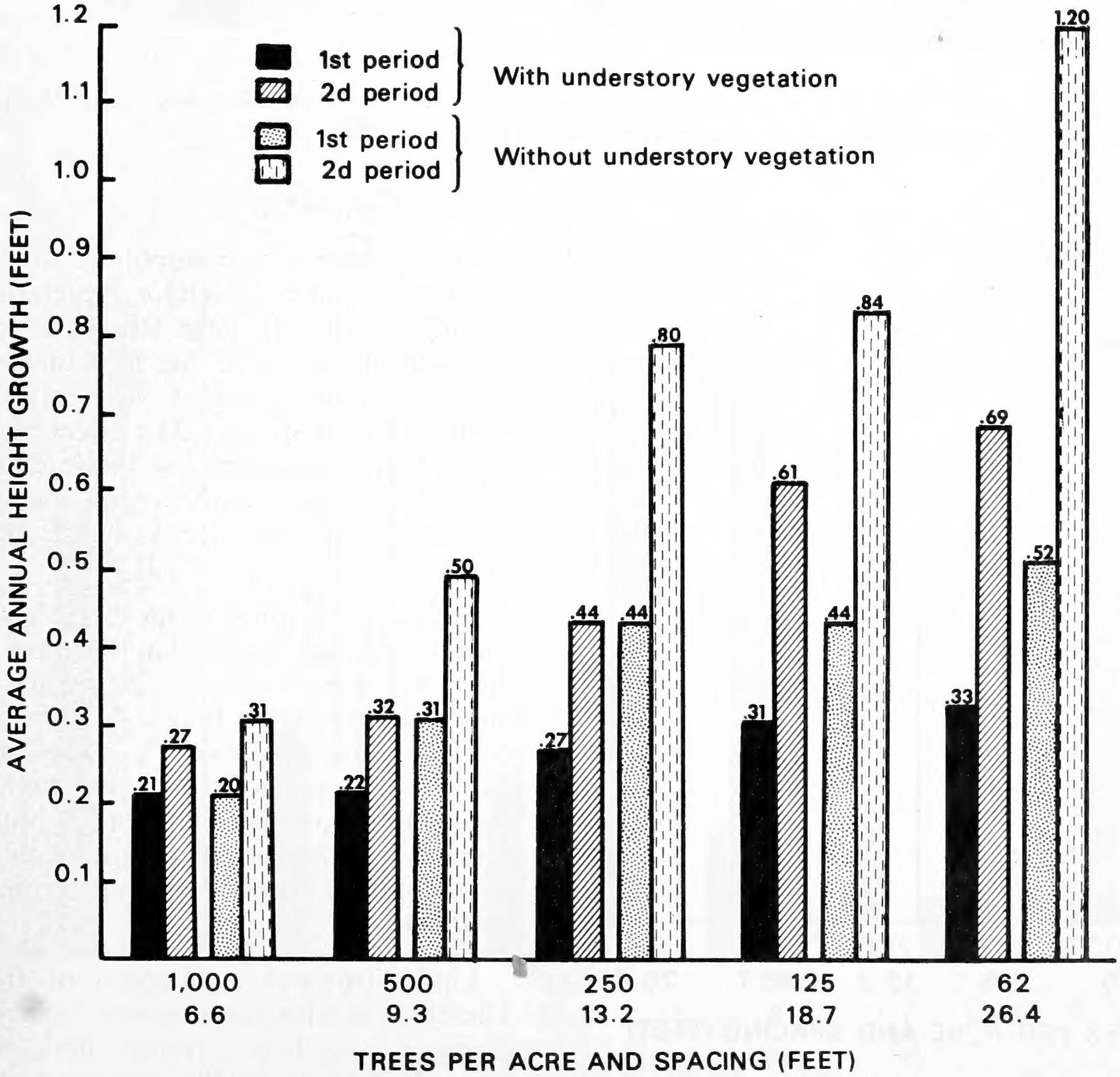


Figure 5.–Average annual height growth during the first and second 4-year growth periods.

Figure 6.–Ponderosa pine released to a wide spacing (1959), shows excellent height growth and possibly undesirable limb development in the lower whorls.

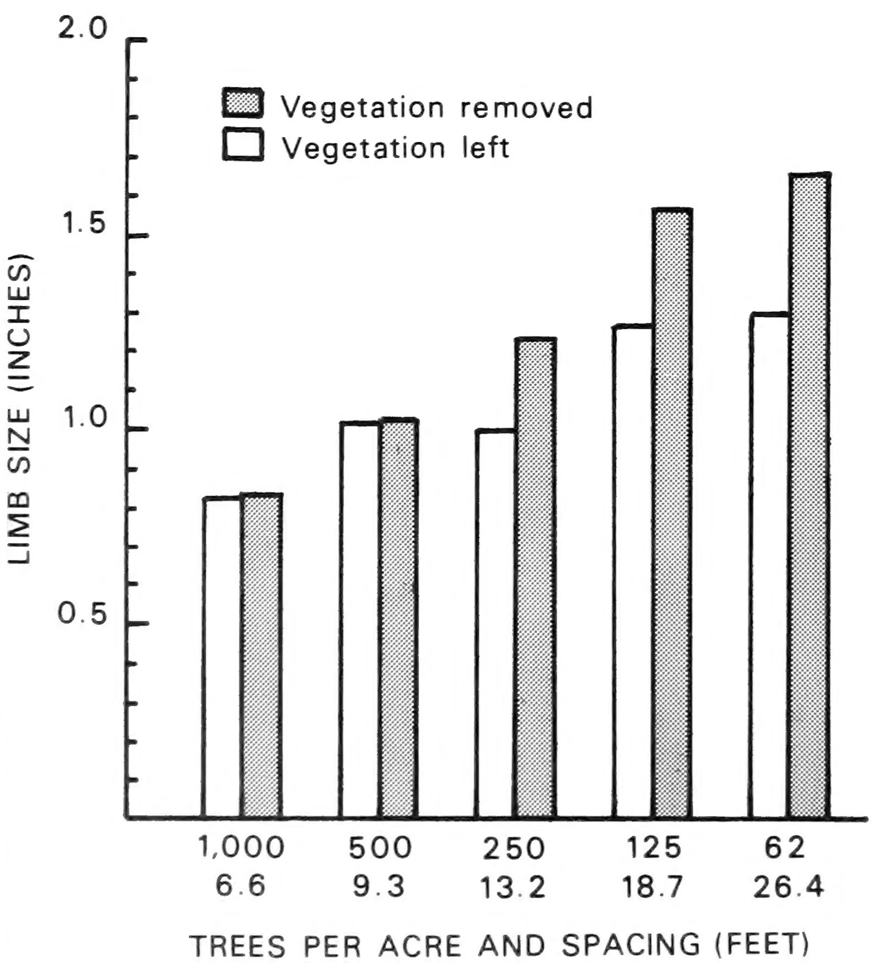


Figure 7.–Average limb size of the six largest limbs on ponderosa pine saplings after 8 years.

Limb Growth

Tree branches also responded to thinning and to removal of understory vegetation (figs. 6 and 7). The six largest branches per tree averaged about 1.7 inches in diameter at the widest spacing compared with only 0.8 inch at the 6.6-foot spacing. The effect of spacing, understory vegetation, and the interaction of spacing and understory vegetation on limb growth are all statistically significant at the 1-percent level of probability.

Increment borings from branches at the widest spacings show that diameter growth rates of 1.4 inches per decade are not unusual on some of the larger branches. Branch whorls on many trees are extremely close together due to their restricted height growth during the suppression period before thinning and overstory removal. These whorls could easily grow together forming an undesirable defect on the bole.

Limb size was a function of tree size. Therefore at wide spacings where current bole diameter was large, average limb size was large. For trees of the same initial d.b.h., branch size increased slightly with spacing.

Cubic Volume Increment

Both reduced tree density and the presence of understory vegetation lowered annual cubic wood production, i.e., more wood per acre was produced at the higher densities where understory vegetation had been removed. But, at the higher densities, small spindly stems which may never reach merchantable size are included in the volume.

The highest tree density where vegetation was removed produced 41 cubic feet per acre per year during the second period. Production decreased with increased spacing. The widest spacing produced only 8 cubic feet per acre per year during the second period where vegetation was left (fig. 8). At the end of the second 4-year period, the highest density where understory vegetation was left contained an average of about 448 cubic feet per acre compared with only 57 cubic feet at the lowest density (table 2). However, the average diameter of the high density stand was 3.2 compared with 4.7 feet at the low density (table 3). Where understory vegetation was removed, average diameter of the widely spaced stand was twice that of the closely spaced stand.

A consistent increase in yearly wood production was observed from the first period to the second (fig. 8). This was most impressive at the three wider spacings where vegetation was removed. Production from the first 4-year period to the second was almost doubled at the 13.2- and 18.6-foot spacings and tripled at the widest spacing.

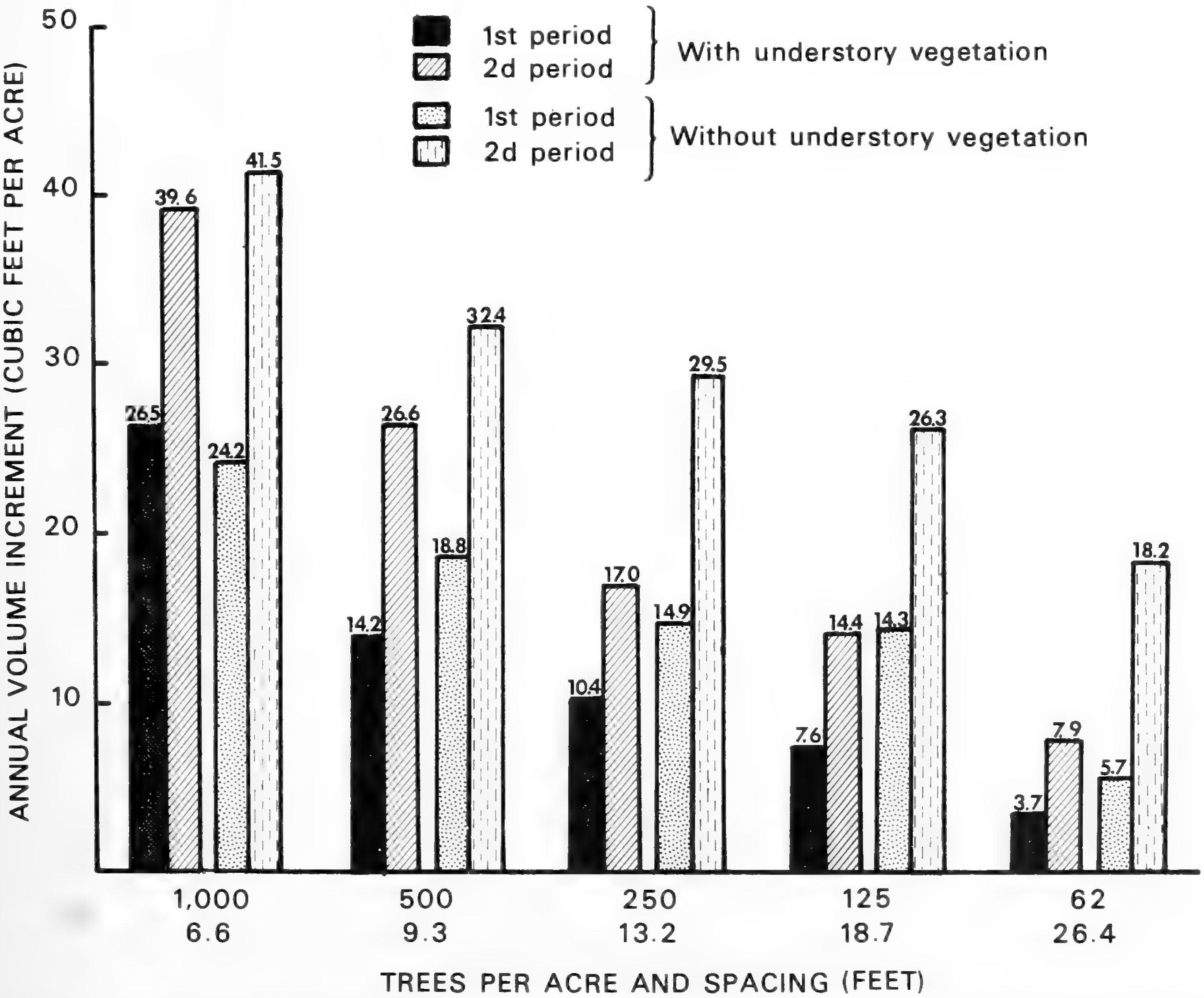


Figure 8.–Average annual cubic volume increment of ponderosa pine saplings during the first and second 4-year periods.

Table 2.—*Net yield of ponderosa pine saplings at the end of the second 4-year period*

Treatment	Trees per acre				
	1,000	500	250	125	62
	Cubic feet				
Vegetation left	448	240	156	113	57
Vegetation removed	396	271	212	195	108

Table 3.—*Average diameter of ponderosa pine saplings in 1959 and 8 years later*

Treatment	Trees per acre				
	1,000	500	250	125	62
	Inches				
Vegetation left:					
1959	2.0	1.7	2.0	2.2	2.1
1967	3.2	3.4	4.0	4.6	4.7
Vegetation removed:					
1959	1.7	1.7	1.9	2.5	2.2
1967	3.1	3.7	4.7	5.7	6.2

Understory vegetation reduced volume increment during both periods, except for the 6.6-foot spacing during the first period. This effect was most pronounced at the two widest spacings during the second period where average reduction of cubic increment was about 50 percent. Furthermore, this increasing deterrent of understory vegetation on growth at wider and wider spacings (spacing and understory vegetation interaction) was significant at the 5-percent level of probability.

The full impact of understory vegetation and tree competition may be more readily comprehended by examining production of the largest diameter trees in each treatment. The cubic volume increments of the 500, 250, 125, and 62 largest diameter trees in each stand treatment are compared in figure 9. Where vegetation was removed, the larger trees in a spacing treatment always produced less annual volume than the same number of trees growing without any other tree competition. For example, the 250 largest trees in a 1,000-tree-per-acre treatment produce about 19 cubic feet per acre, but where only 250 trees are left, production is almost 30 cubic feet.

On the other hand, where vegetation is not removed, there is almost no difference between

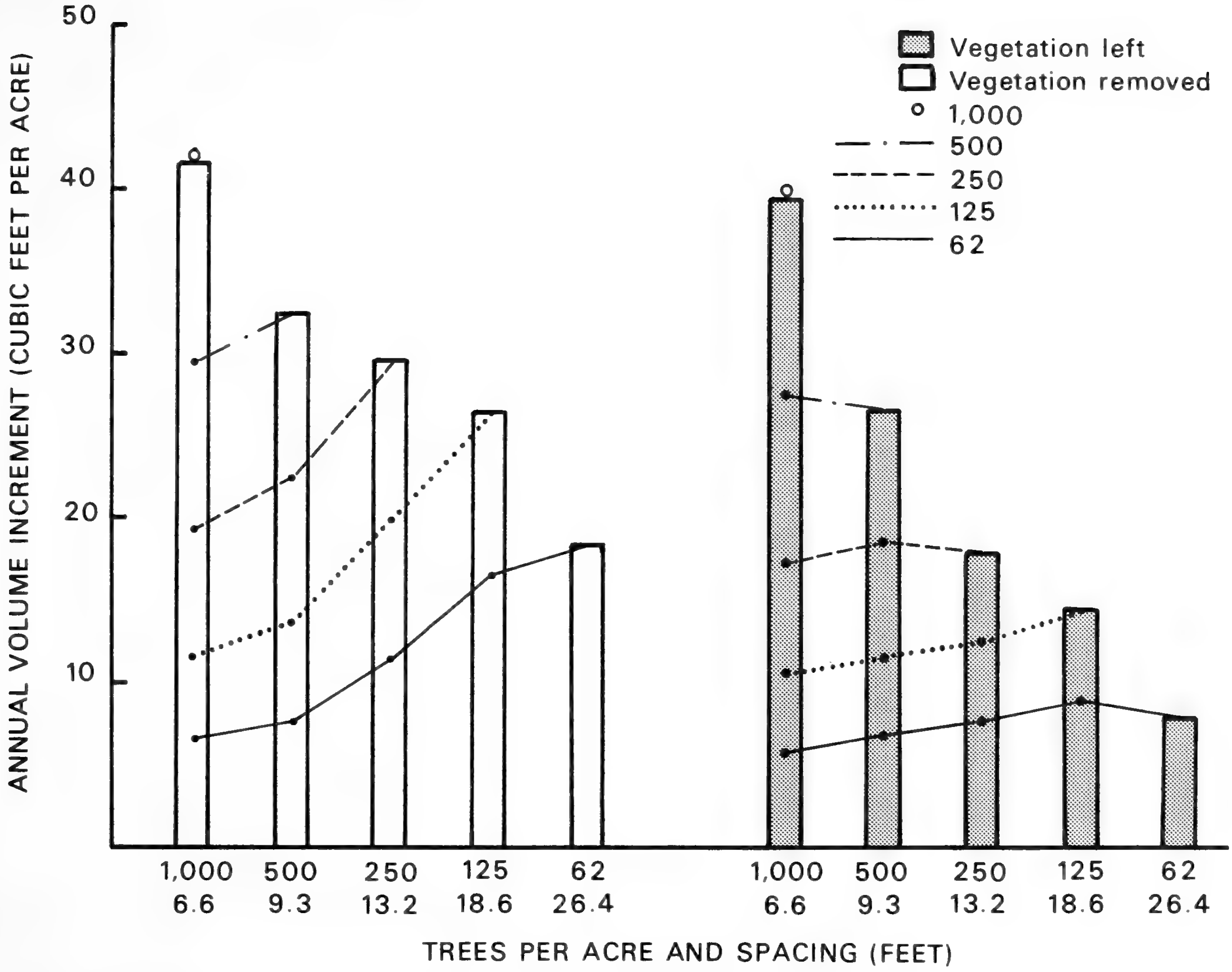


Figure 9.–Periodic annual volume increment of ponderosa pine saplings thinned to various spacings (1963-67). Bars show increment for total number of trees at each spacing. Points within bars show increment of the stated number of the largest well-distributed trees within the stand.

production rates for the same treatments and tree numbers. For example, there is little difference between the volume production of the "best" 250 trees in the 1,000-tree-per-acre treatment compared with that in a plot density of 250 trees. Similar conclusions can be drawn from other treatments and tree numbers. Evidently the growing space created by fewer and fewer trees was soon occupied by understory vegetation which offered as much competition or sometimes more than many more trees.

This suggests that maximum benefits from thinning will be gained only by maintaining some suppression of understory vegetation for at least part of the life of the stand.

Mortality

Only 12 trees died of a total of 2,232. Two-thirds of this mortality occurred where 1,000 trees per acre were left and was due mostly to *Armillaria* root rot, although the *Armillaria*-caused mortality was not related to spacing.

In terms of cubic volume, losses were extremely small. For example, the heaviest loss was at the 6.6-foot spacing where vegetation was left, and this amounted to only 0.5 cubic foot per acre per year during the last period. Losses on the other treatments were 0.1 cubic foot or less. No mortality took place during the first period.

Other Thinning Effects

The tree spacing to be selected in a precommercial thinning depends, in part, upon the total "product mix" desired from the forest, that is, wood, water, and forage. Narrow spacings tend to increase total wood production, if small trees can be used. On the other hand, wider spacings tend to favor forage and water production. Therefore, an understanding of the effect of thinning on forage and water is important in selecting an appropriate initial spacing.

Figure 10.–Ponderosa pine saplings thinned to a wide spacing (1959). Understory vegetation left (top). Understory vegetation removed (bottom).

Forage.–Thinning stimulated not only growth in diameter and height of trees but also growth of understory vegetation (figs. 10 and 11).

Four years after thinning, it was obvious that most thinned plots in this experiment where understory was left had considerably more understory vegetation than nearby unthinned stands. Furthermore, by this time there was a tendency for greater amounts of understory vegetation to occur at wider spacings except for the widest spacing. By 1967, we were tempted to speculate that vegetation was responding to the additional amounts of light, soil moisture, and nutrients provided by wider spacing, as differences in amounts of vegetation present at the various spacings were significant at the 5-percent level of probability. In addition, orthogonal comparisons showed a trend toward more understory vegetation at wider spacings, although the 125-tree-per-acre treatment averaged more understory vegetation than the 62-tree-per-acre treatment (as indicated in figure 11). Statistical tests showed no real difference between the two treatments.

Vegetation crown cover increased with time through all the spacings tested (fig. 11). For example, at the 6.6-foot spacing, density percentages ranged from 18 percent in 1959 to almost 29 percent in 1967 and at the 18.7-foot spacing, from about 29 to 47 percent.

Bitterbrush was the principal understory species, making up about 45 percent of the total vegetation in 1967. Snowbrush and grasses were also present but in lesser amounts. There was a surprising increase in sedge (15 percent of the area) at the 18.7-foot spacing, where in 1959 sedges had covered only 5 percent of the ground. Bitterbrush and Ross' sedge were the most responsive understory vegetation species to overstory removal and thinning.

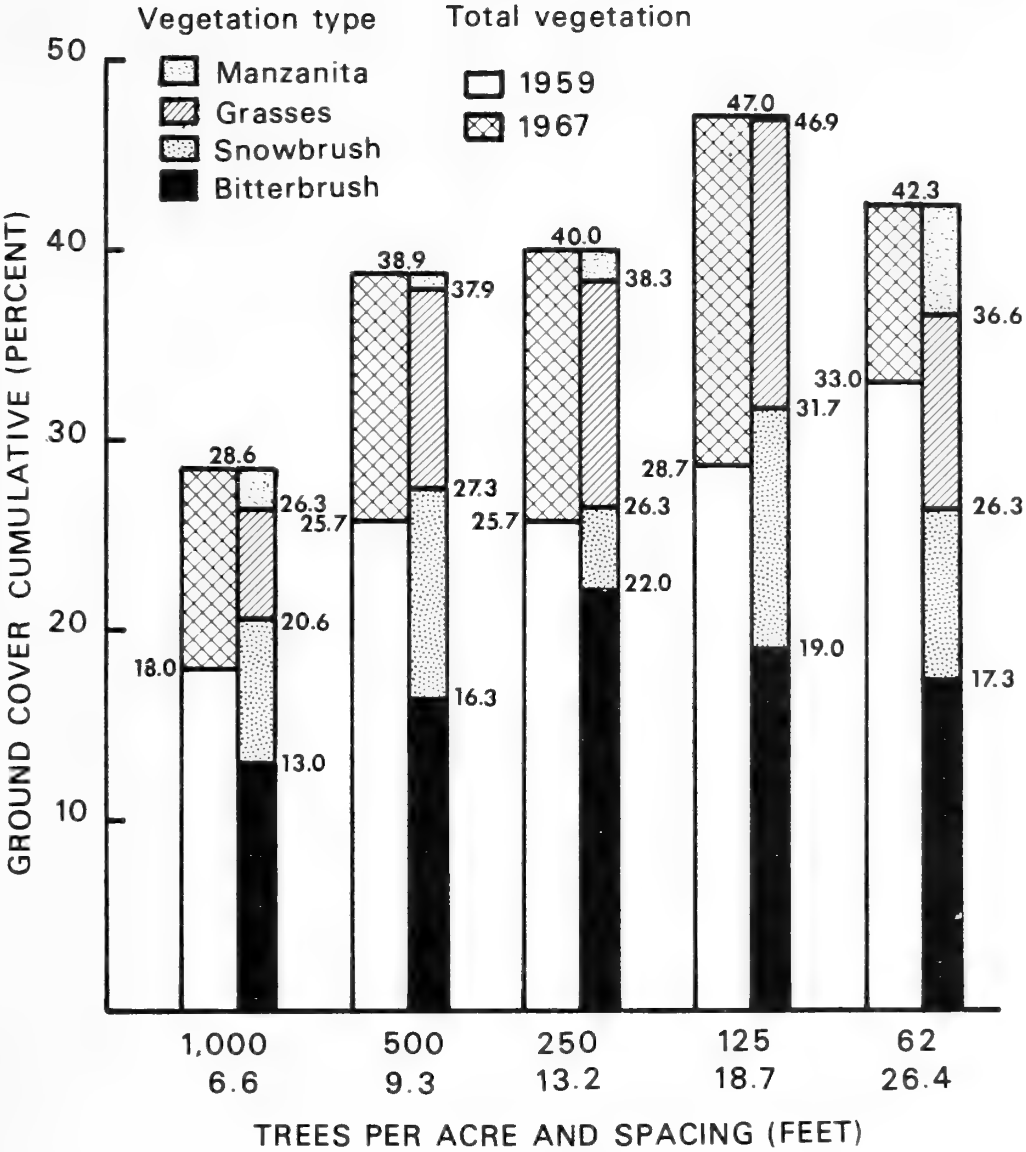


Figure 11.—Average percent of ground covered by understory vegetation in 1959 and 1967 and percent covered by type of vegetation in 1967.

These results indicate possibilities for increasing forage production for domestic livestock and wildlife. Thus, forage production and nutrition are being evaluated in this study (*5*) and in other spacing studies in ponderosa pine (*9*).

On plots where understory vegetation was removed and the ground kept clean, sedge was most difficult to eradicate. After sedge plants were removed with grub hoe, 1 year later they were established again and had developed extensive root systems. Bitterbrush seedlings were visible 2 to 3 years after hoeing.

Water use.—Overstory harvest, thinning, and understory vegetation removal have completely changed the water-use characteristics of this site. More water has become available for trees and possibly streamflow. When the soil moisture use in a stand containing mature overstory, dense understory trees, and natural understory vegetation is compared with soil moisture used in a stand thinned to 125 trees per acre and the understory vegetation suppressed, we find that moisture left in storage at the end of the growing season increased several years during and after 1961 by almost 50 percent. To illustrate, figure 12

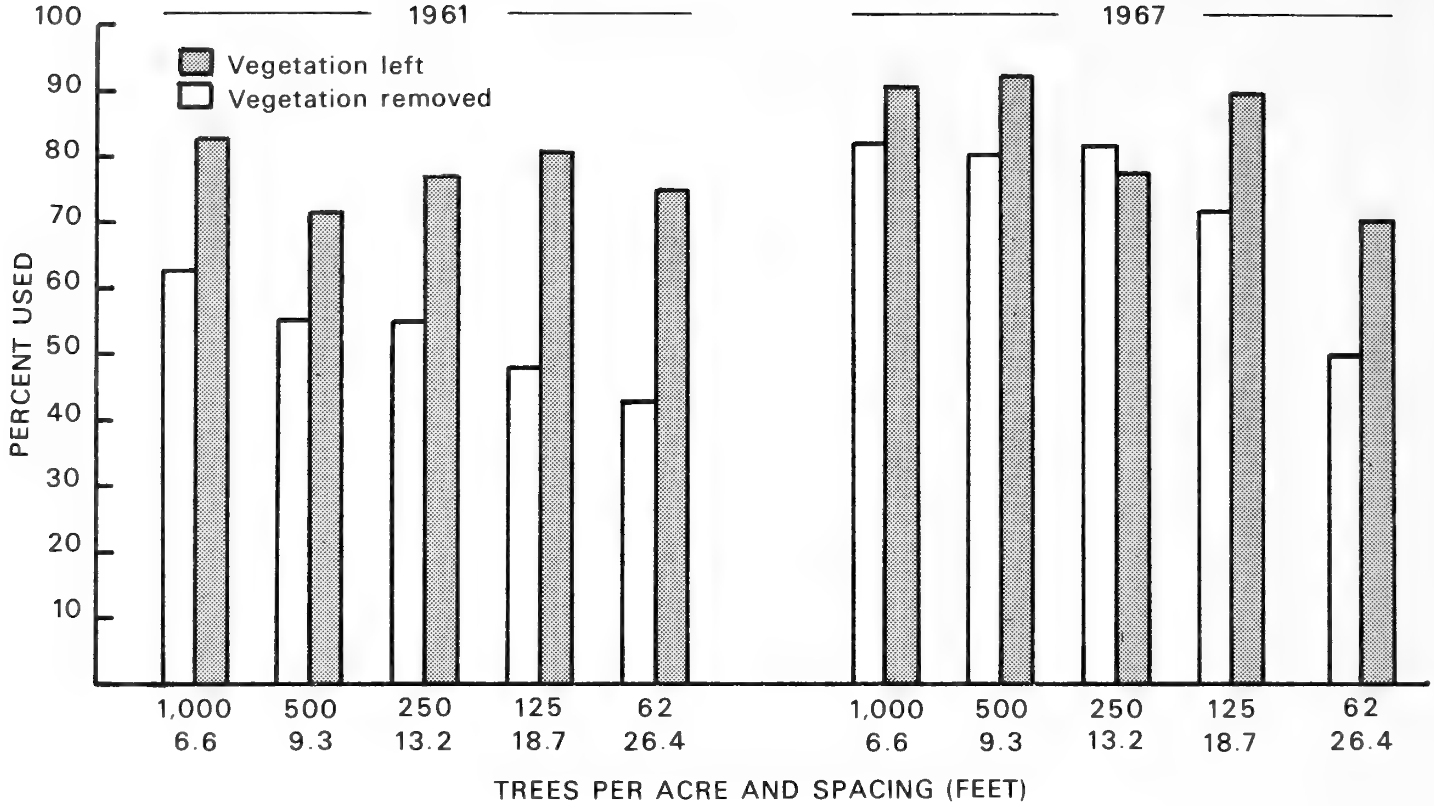


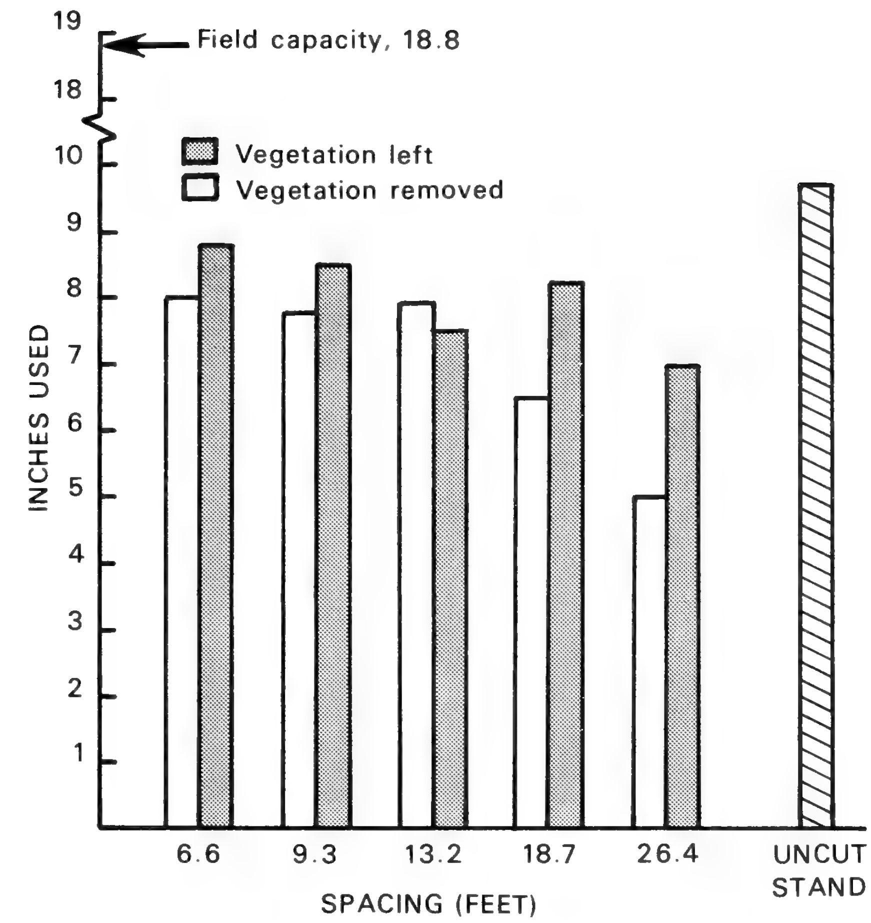
Figure 12.–Percent of available soil moisture used by ponderosa pine sapling stands thinned to different spacings.

shows that the 125-tree-per-acre treatment when vegetation was removed used only 48 percent of the soil water that is available for all vegetative growth. Other treatments show more or less water contributing to deep storage depending on tree density. If we thin to 125 trees per acre and let understory vegetation develop naturally, the gain over the untreated stand is about 20 percent. Even though this estimate is slightly high because of sampling point location, it does appear that the stand treatment would promote notable contributions to deep storage in some watersheds.

In 1961, several years after thinning, all plots where understory vegetation was left used an average of about 77 percent as much water as used by the untreated stand (fig. 12). In contrast, plots where vegetation was removed used only 53 percent of that used by the uncut stand. Six years later, in 1967, these percentages had risen to 83 and 73, respectively. Evidently, enlarged root systems and greater transpiring leaf area accounted for these changes. During the 8 years of observation, water-use figures indicate that the soil site complex was gradually being occupied by trees and understory vegetation, but total use had not been reached. For example (fig. 13), the untreated stand used almost 10 inches of water in the 5-foot profile, but the two narrowest spacings where understory vegetation was left used slightly less than 9 inches. Sensing only at the most critical position in the stand would indicate that it may not be long before complete utilization of the site will occur at the narrow spacings. On the other hand, where vegetation was removed and trees widely spaced, it may be some time before the site will be completely utilized.

A surprisingly small amount of soil moisture held in the 5-foot profile at the beginning

Figure 13.–*Inches of water used by ponderosa pine sapling stands thinned to different spacings and by the uncut stand (1967).*



of the growing season was actually used by the untreated stand. For example, in 1967 about 3.8 inches of water per foot was present in the profile, yet only 52 percent of this soil water was actually used by a stand that was obviously occupying the site. Some of this nonuse can probably be attributed to the lack of roots in the infertile C horizon. Thus, water is withdrawn heavily from the A, AC, and D horizons only. Dyrness and Youngberg (*7*) observed this on Lapine soils farther south in central Oregon and attributed it to a lack of fertility in the C horizon. Also, pumice subsoils are not easily penetrated by roots (*11*), i.e., the C horizon offers a physical barrier to root development. Where burrowing animals and windthrow have caused mixing of the C horizon with the buried soil, much greater root development has taken place and therefore greater water use. In addition, Cochran (*4*) reported that poor contact between plant roots and individual particles in pumice soils may impede the flow of moisture to the roots.

CONCLUSIONS

After 8 years of observation, the following may be concluded:

1. Diameter and height growth of sapling ponderosa pine may be accelerated by increasing growing space per tree and removing competing understory vegetation.

2. Limbs on released trees also respond to increased growing space and removal of competing vegetation.

3. Maximum benefits to tree growth from thinning will be gained by maintaining some suppression of understory vegetation development over at least part of the stand's life.

4. Thinning to a wide spacing and continued suppression of understory vegetation could appreciably increase water yield for domestic use.

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A tree spacing study in central Oregon showed that sapling ponderosa pine will respond to a wide range of spacings but suggests that maximum benefits from thinning will be gained only by suppressing understory vegetation. Diameter and height growth of trees were reduced 40 percent at the widest spacing by understory vegetation competition.

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